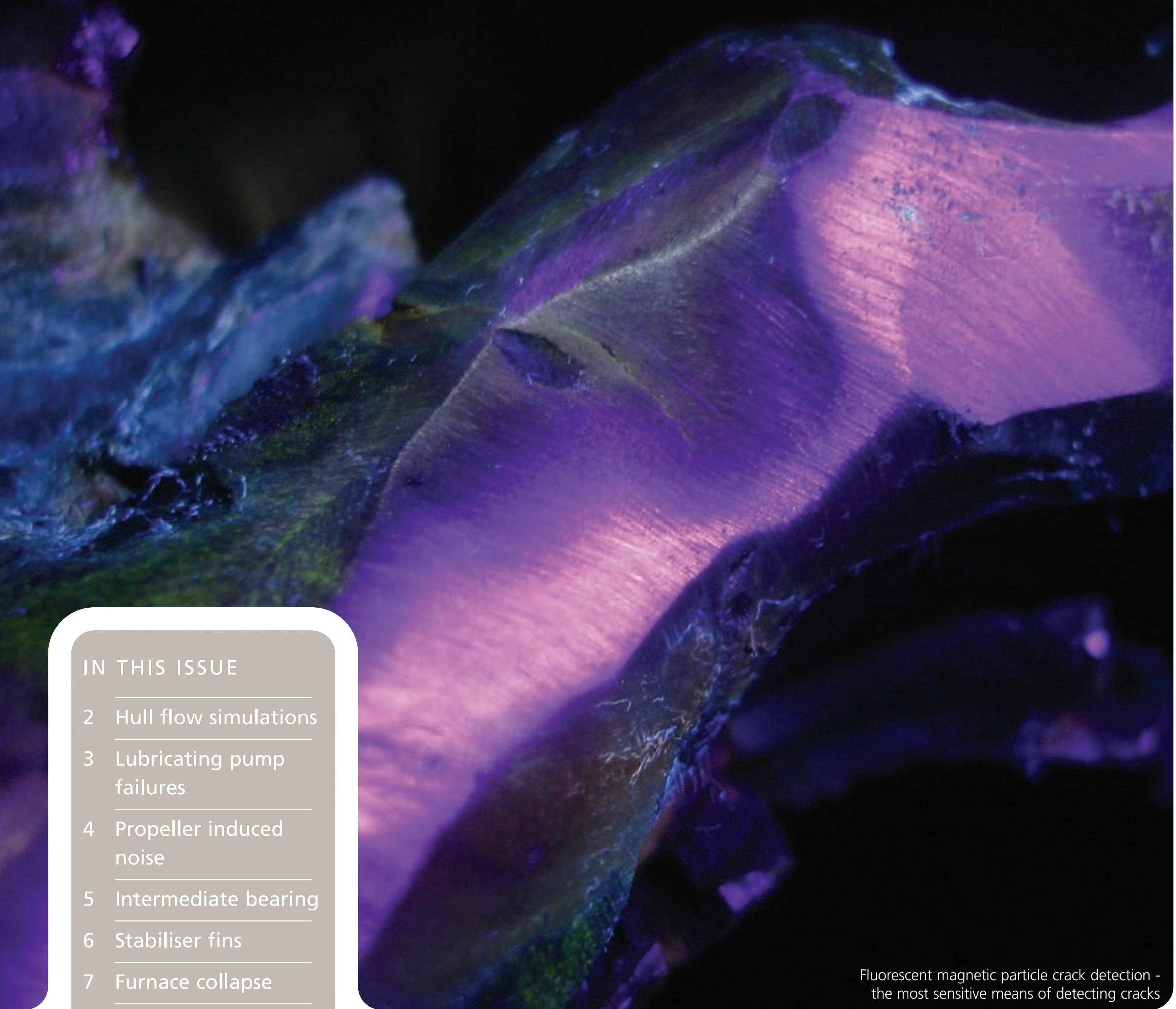
TECHNICAL MATTERS

JUNE 2009 Issue 4

Welcome to the fourth issue of *Technical Matters,* a Lloyd's Register publication containing case studies covering technical issues and their solutions.



Fluorescent magnetic particle crack detection - the most sensitive means of detecting cracks

IN THIS ISSUE

Lloyd's Register

CASE STUDY 1

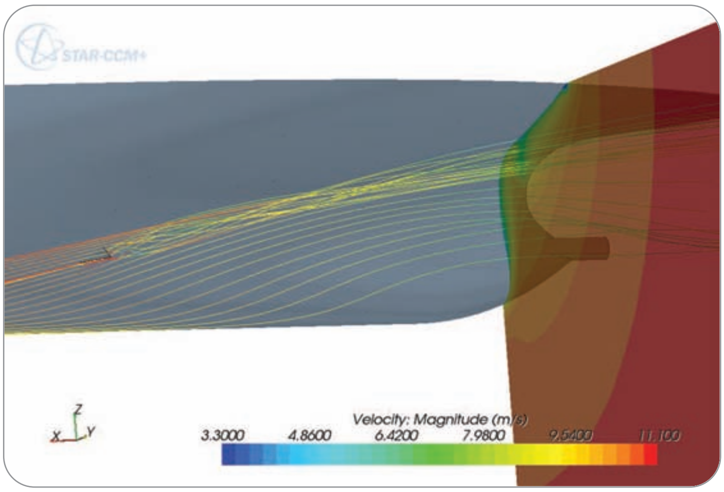
Hull flow simulations

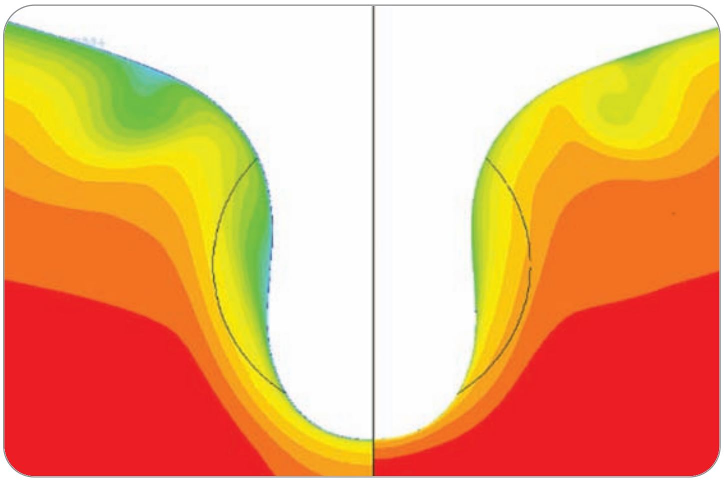
SUBJECT VESSEL TYPE
Container Ship

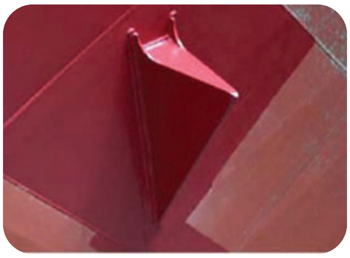
ISSUE
CFD assessment of vortex generator

Lloyd's Register Technical Investigations (TI) has, for the past fifteen years, been actively engaged in studying wake fields with the use of Computational Fluid Dynamics (CFD). This research has resulted in some interesting insights to the developments of flows over the submerged afterbody, in support of more efficient and more reliable ships.

A common application of CFD methods is to improve the prediction of propeller inflows, i.e. ship wakes. These methodologies have been applied to a medium sized containership which suffered from high vibration and noise levels in the all-aft accommodation. To remedy the high vibration and noise levels, this ship was fitted with vortex generators to alter the inflow into the propeller.







The result was a reduction in hull pressures radiated from the collapsing sheet and tip vortex cavitation on the propeller.

Two CFD models were analysed: one with, and one without vortex generators added. It was found that with addition of the vortex generators a reduction in propeller inflow velocities near top dead centre was achieved, as desired. The vortex generator was also found to reduce the axial velocity elsewhere in the propeller disc.

The traditional way of analysing propeller inflow wakes consists of measuring the wake in a conventional towing tank on a Froude scaled model, without an operating propeller. Although such methods have, in the past, been used to provide hull pressure and propeller inflow predictions, they have some shortcomings; including problems associated with post experiment corrections which must be applied to counteract scaling effects, and the absence of the interactions between the propeller and hull.

CFD analysis allows detailed examination of flow features that would not be possible using model tests. The flow can be visualised in various ways such as viewing of the vorticity in the wake and examination of streamlines around the dynamic ship form.

LESSON

Computational Fluid Dynamics provides an unrivalled level of detail of the local flow behaviour enhancing understanding and helping find optimal solutions. CFD methods can and should be used to address shortcomings in the traditional methods of predicting aft-end flows.

CASE STUDY 2

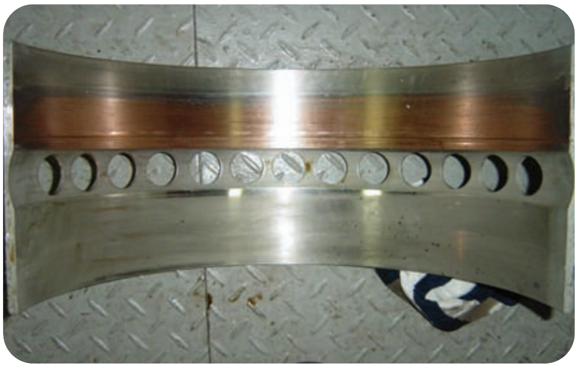
Lubricating pump failures

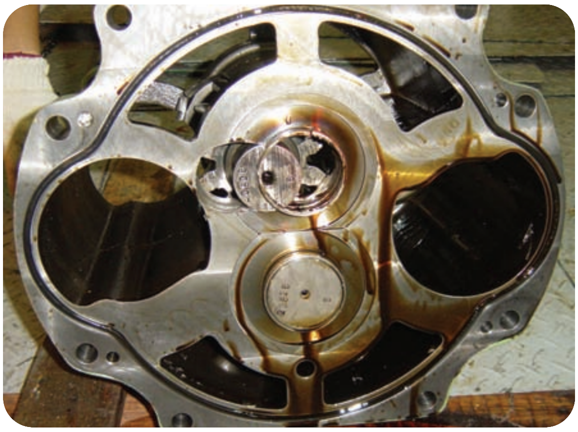
SUBJECT VESSEL TYPE
Container Ship

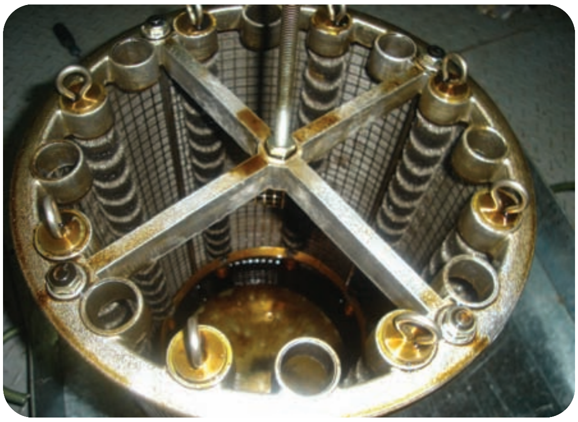
ISSUE
Repeated failure of lubricating oil pumps

A small container ship had problems with its main engine driven lubricating oil system since construction. There were three separate failures of the two lubricating oil pumps. In each incident, one of the lubricating oil pumps failed catastrophically. The principal damage caused was the failure of a number of the connecting rod bottom end bearings. After each failure a large amount of both fine and coarse metal debris was found in the oil filtration system. Lloyd's Register Technical Investigations (TI) was asked to attend the vessel to investigate and advise.

Prior to each failure the lubrication oil pressure was reported to have fluctuated rapidly. Such a characteristic is often indicative of air pockets travelling through the oil suction system.







A trouble-shooting programme was undertaken when the ship was in port for repair after the third pump failure. The programme involved running the engine under a number of steady conditions using the auxiliary electrically driven lubricating oil pump.

A number of problems were identified, including:

- aerated oil being delivered to the pump suction pipes due to the pump suction and engine discharge pipes being in close proximity;
- the accumulation of air in the suction system due to pipe geometry;
- contamination of the lubricating oil with fine metal particles possibly extending back to original construction.

An extensive range of modifications were made to the sump tank and the off-engine lubricating oil pipework system. A thorough cleaning of the entire system was also carried out to remove all metal debris.

A one-hundred hour sea trial was conducted on completion of the pipework modifications. Technical Investigations (TI) attended during the sea trial and provided real time condition monitoring of the engine driven pumps.

On completion of the sea trial, both of the lubricating oil pumps were removed and dismantled for inspection. The pumps were found to be in as-new conditions. It was concluded that the circumstances that caused the previous failures had been rectified and no further problems have been reported by the owner.

LESSON

Quality control and cleanliness procedures must be followed during shipyard construction and maintenance. While it is preferable to eliminate problems such as aeration during the design stage it is possible to subsequently conduct remedial work to minimise occurrences and impact.

CASE STUDY 3

Accommodation block noise

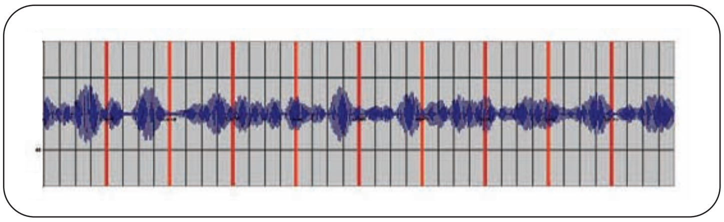
SUBJECT VESSEL TYPE
General Cargo Carrier

ISSUE
Aft-end noise from tip vortex cavitation

Sister ships can often experience similar in-service problems which arise due to common design or manufacturing faults. When a ship builder reported that disturbing bursts of noise, close to the shaft rate, were reported in the aft areas of the accommodation blocks of the first four sister ships in a series of small general cargo carriers, Lloyd's Register Technical Investigations (TI) was consulted.

The vessels were fitted with a four bladed, controllable pitch propeller installed in a high efficiency duct with a relatively bluff headbox connection to the hull. Prior to TI's involvement, fairing pieces had been applied to the duct headbox with little success and the blades of one vessel had been replaced with spares. Some deviations in the allowable tolerances had been identified by the builder.

The reported nature of the noise strongly suggested a type of propeller cavitation as the primary source and hence sea trials were organised in order to define the noise and cavitation characteristics in both the load and ballast conditions.



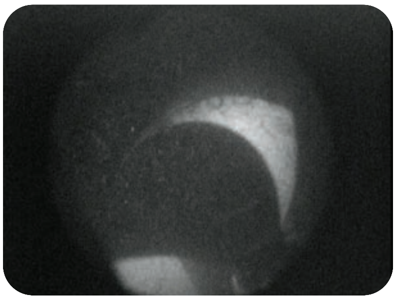
- propeller observations using a borescope and low light video system.
- accommodation noise measurements.
- vibration measurements.
- hull pressure measurements.

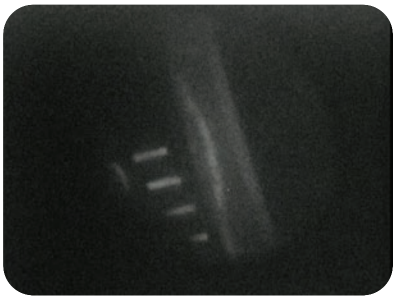
Borescope observations of flow at the duct exit plane showed variable length sections of a strong cavitating tip vortex emerging from the duct at shaft rate. Tip vortex cavitation structures were also observed within the duct, some disintegrating. Audio and video recordings showed a correspondence between the dominant collapse of the tip vortex emerging from the duct.

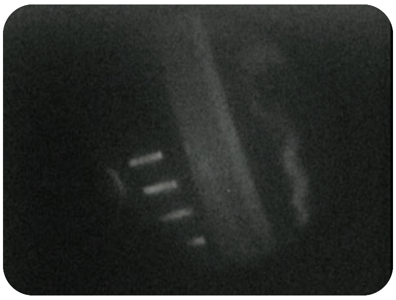
Pressure and vibration pulses contained low-frequency and broadband activity; the latter from bursts of energy in the frequency range 90-120 Hz.

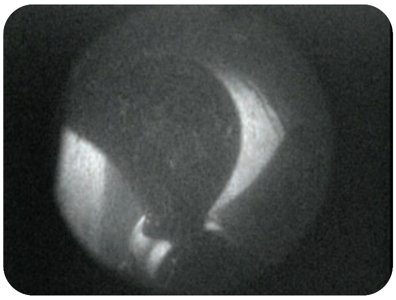
This was the first known case of a once per revolution broadband noise source which was not from a "singing propeller". It was concluded that dimensional variations on the propeller and duct may have led to the formation of the strong cavitating vortex. Recommendations were made to survey the other ships and to pay close attention to the blade inspection process, assembly and installation inside the ducts.

Palliative solutions included injecting air into the upper duct region, applying acoustic damping materials and insulating the stairwell adjacent to the cabins experiencing high noise levels. Ultimately the problem was tackled at source and a redesigned propeller was fitted.









LESSON
Conventional vibration and noise measurements are often insufficient to identify the types of the cavitation and such problems may be solved by viewing the blades and the tip vortex structures with a borescope and a video capture system

CASE STUDY 4

Intermediate bearing

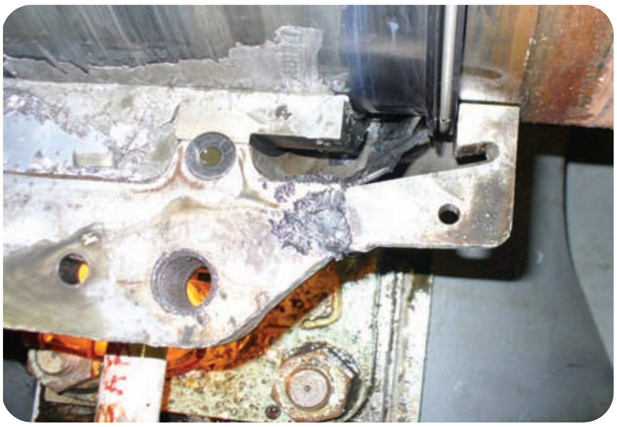
SUBJECT VESSEL TYPE
Chemical Tanker

ISSUE
Failure of the intermediate shaft bearing

During a partially laden voyage a direct drive diesel powered Chemical Tanker suffered a severe failure of the intermediate shaft pedestal bearing. Significant wiping damage occurred to the bearing white metal surface requiring the ship to be towed to port for repair.

The vessel had recently completed a five yearly dry-dock survey during which the propulsion shafting had been dismantled for inspection. The inspection had revealed no problems and the shafting was refitted.

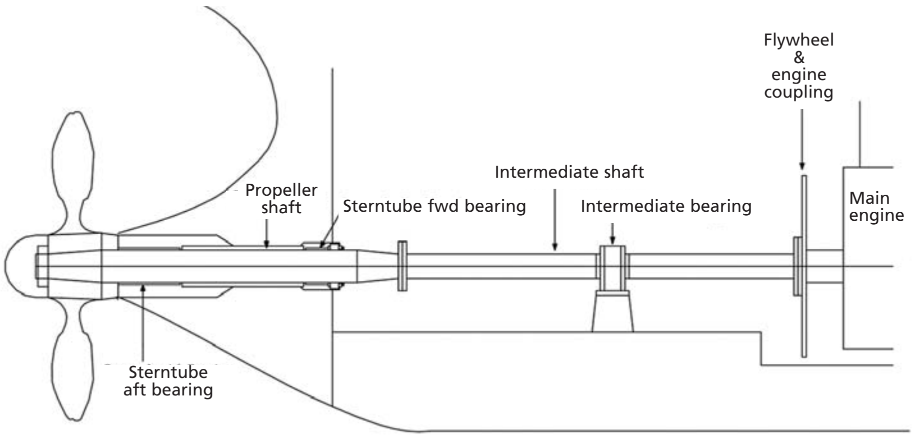
Following the failure bearing loads and shaft deflections were measured using the jack-up technique. The results revealed an unsatisfactory distribution of load along the shafting system length. In particular it was found that the forward sternbush and the second aft engine bearing had insufficient downwards load. The second aft engine main bearing was considered to be at risk of fatigue damage.



Calculations revealed that the scope for improvement of the alignment conditions by adjustment of the intermediate bearing was limited. Loading of the engine second aft main bearing by fitting an upwards offset bearing shell was therefore recommended. Such adjustment would improve the loading on the engine bearing but would have negligible effect at the forward sternbush.

It was found by calculation that the satisfactory operation of the shafting system could be achieved even though the forward sternbush was only lightly loaded. This was supported by recent operating experience.

Following the completion of the refitting a sea trial was carried out where the helm was held over for prolonged periods of time putting strain on the shafting system. During these turns, the aft sternbush and intermediate bearing temperatures remained stable. Also there was no abnormal vibration found during increases and decreases in shaft speed.



LESSON
Shafting systems require careful alignment, especially when the shaftlines are short and stiff. Appropriate combinations of measurements and analysis can enable correct alignment of the shafting components.

CASE STUDY 5

Stabiliser fins

SUBJECT VESSEL TYPE
Passenger/Ro-Ro ship

ISSUE
Stabiliser fin failure

Two retractable stabilising fins were attached to the sides of a Ro-Ro cargo and car carrier where, by adjusting the angle of attack, they could provide a variable lifting force to reduce vessel roll.

After three years in service one of the stabilisers was found to be missing, having failed due to fatigue some time before.

By examining the remaining part of the fatigued stabiliser stock at the Lloyd's Register Materials and NDE Laboratory it was found that a fatigue crack had grown from a single initiation point, 5 mm below the shaft surface, in the fusion zone between a weld and the base material. Welded regions often show characteristic non-uniformities and inclusions at the base material interface. It was also found that no heat treatment had been undertaken to eliminate residual stresses. These residual stresses can often encourage crack growth.

It was calculated that the shaft had a low factor of safety against the bending loads imposed on the shaft due to roll of the ship in service. The low factor of safety was apparent from the fatigue pattern as the fatigue crack had propagated for only 15% of the shaft diameter before rapid brittle fracture finally occurred.

During the initial stages of crack growth there were three distinct bands of relatively slow propagation interspersed with two narrow bands of more rapid propagation. These changes in crack growth rate indicated significant changes in service loading, such as loading induced by especially rough sea conditions.

Recommendations were made that the stabiliser stocks on sister vessels should be examined visually and by non-destructive testing for the presence of cracks. Recommendations were also given to fitting shafts with an increased operating margin against imposed bending loads.

LESSON

Poor manufacturing practises and component selection can often lead to early failure during service life. Understanding the mechanisms of failure can lead to more robust solutions.

CASE STUDY 6

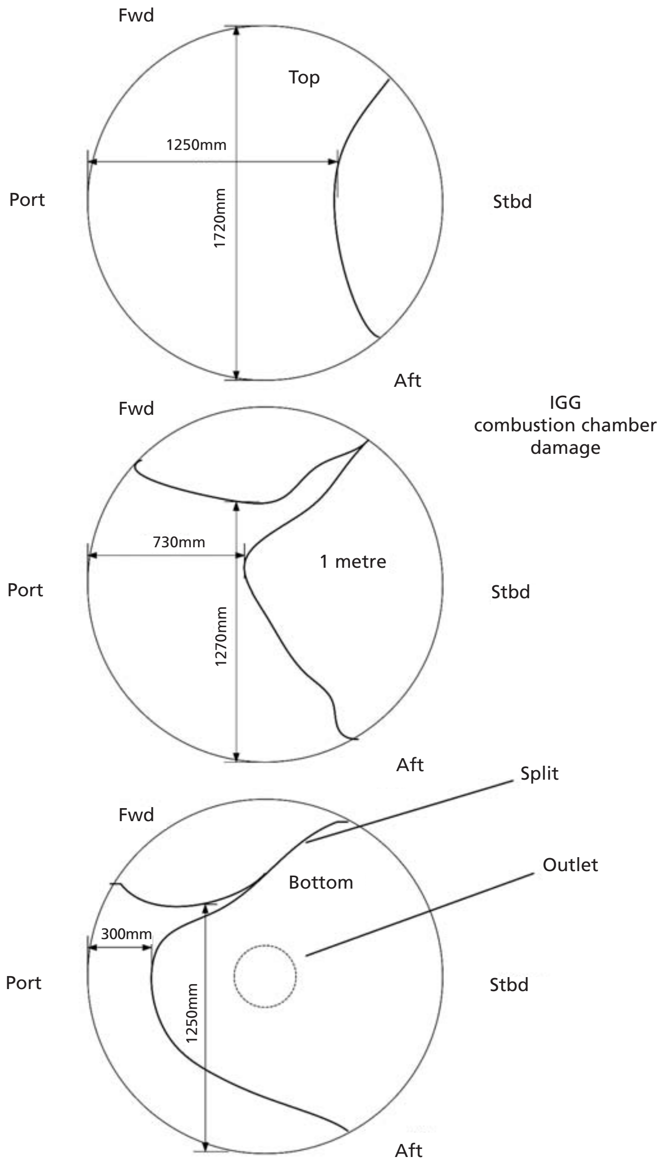
Furnace collapse

SUBJECT VESSEL TYPE
LNG Carrier

ISSUE
Inert gas generator furnace collapse

Following the collapse of an Inert Gas Generator (IGG) furnace onboard a LNG carrier an investigation was carried out into how the controls and instrumentation could have allowed the failure to occur.

The IGG was cooled using seawater taken from the ballast system, and the hot discharge water was returned to the sea through a position controlled effluent regulating valve.



The inert gas and effluent pressures were compared using a Proportional Integral (PI) controller which controlled the position of the effluent valve. It was found that the two pressure transducers of the PI controller were both blocked with debris, giving false readings, therefore causing the effluent valve to be incorrectly positioned. At the time of the furnace collapse the valve was found to be fully closed.

The combustion chamber flooded causing the Level Shut Down Alarm to operate. The alarm appeared to have tripped the ballast pump but not the burner flame. The resulting shortage of water to the lit furnace caused overheating of the combustion chamber wall which yielded and collapsed.

The Temperature Shut Down Alarm did not detect the rise in temperature of the combustion chamber wall due to its remote location from the point of failure.

It was therefore possible for the IGG burner to continue to operate with no apparent external indication that failure had occurred.

A number of recommendations were made to modify the method and manner by which the system shut off the burner if the cooling water were to be reduced or blocked. It was also recommended to include a mechanical fail safe device which would allow the continued flow of cooling water if the effluent valve were to close at an inappropriate moment.

LESSON
Safety critical systems should always be designed with a certain degree of redundancy. By anticipating and planning for all possible risks at the design stage hazards can usually be avoided and/or mitigated.

CASE STUDY 7

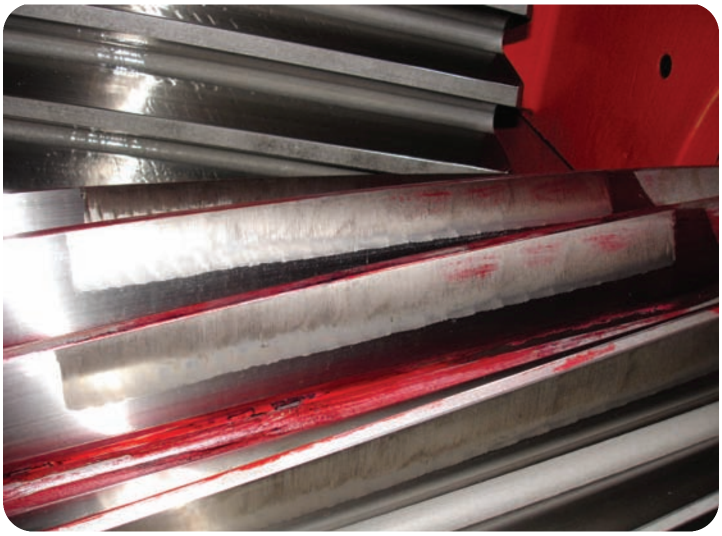
Gear scuffing

SUBJECT VESSEL TYPE
LNG Carrier

ISSUE
Scuffing of the main reduction gearing

Severe scuffing damage occurred on the teeth of the two input pinions and main wheel of the main propulsion gearing during trials of a newly built diesel electric LNG carrier. The propulsion system consists of twin electric motors driving a single output main propulsion shaft and fixed pitch propeller through single reduction, single-helix gears. Lloyd's Register Technical Investigations (TI) was asked to attend onboard at the newbuilding yard to inspect the tooth flank damage and assist with the failure investigation.

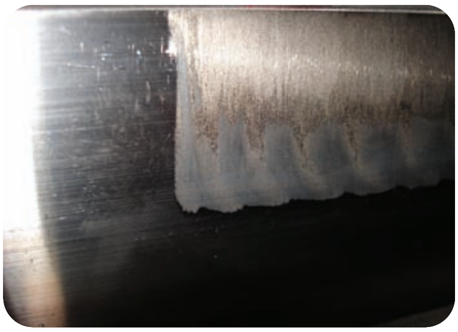
Failure of the gears was traced from trial records to occurring during a rapid acceleration test. In this test, the propulsion plant was accelerated from stationary to full away in a little over eleven minutes.

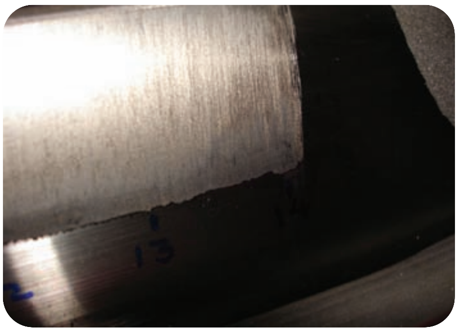


The scuffing damage was due to a breakdown of the elasto-hydrodynamic oil film which should normally be present between mating gear teeth. The breakdown resulted from a combination of the selection of the pinion gear tooth-end design and the rapid rate of torque input to the pinion gears from the electric propulsion motors. It was considered likely that the damage was initiated at the starboard mesh and then transferred to the port mesh in way of the main wheel.

The damaged pinion gears were returned to the gearing manufacturer for remedial machining including design modifications to the gear tooth flank. The main wheel tooth flanks were polished in-situ.

Following repair, the reduction gearing successfully completed sea trials. This was achieved by modifying the pinions helix correction and end relief. The propulsion electric motor speed-torque characteristics had also been modified to reduce the initial rate of torque delivery to the pinion gears.





LESSON
Gear meshing design can be complex. Precision must be employed when cutting gear teeth and aligning the gear wheels to ensure good contact between the mesh. Correct lubrication is also essential in preventing premature gear failure.

CASE STUDY 8

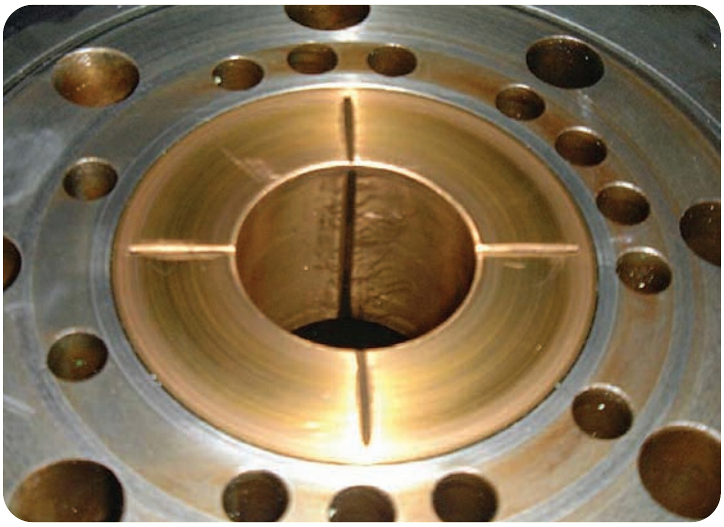
Air start manifold explosions

SUBJECT VESSEL TYPE
Oil Tanker

ISSUE
Main engine air start manifold explosions

During testing of the stop-start function of an oil tanker main diesel engine an explosion in the main starting air manifold was experienced. Damage was sustained to the manifold itself, the automatic valve and the inlet pipe to a cylinder unit. The explosion occurred on two separate occasions before Lloyd's Register Technical Investigations (TI) was called in to determine the cause.

Examination of the main engine air start system revealed the following:



- the air start valves fitted to the engine had air leaks in all valves in way of the valve seat:
- the starting air manifold and the air inlet pipes had an internal coating of a black oily/sooty substance (consistent with the physical characteristics often found after an explosion). Oil sludge deposits were removed from the air start manifold and sent for analysis, proving that the source of the oil contamination was the main air compressor lubricating oil:
- during engine operation the air start manifold contained a large amount of mist and smoke.

It was found that the air distributor, which provides the timing for opening the air start valves, was worn excessively by the ingress of hard foreign objects. The wear allowed air to enter unintended air start pilot lines, opening both correct and incorrect air start valves. Firing from the main engine cylinder had then allowed an ignition source into the air start manifold, igniting the mist and oil deposits and hence causing the explosions.

The system was repaired by replacement of the air distribution system along with machining and lapping of the air start valve seat. The air start manifold, piping and associated machinery were also thoroughly cleaned. Recommendations were also made to overhaul the main air compressor lubrication system, to prevent the air start manifold becoming contaminated with lubricating oil.

LESSON
Good maintenance and cleanliness procedures should always be followed. Prevention can often avoid not only an expensive breakdown but a dangerous situation from arising.

CASE STUDY 9

Cylinder head

SUBJECT VESSEL TYPE
Cruise Ship

ISSUE
Cylinder head damage

A diesel electric propelled cruise ship sustained extensive damage to a cylinder head, valve and running gear in one of its auxiliary engines. A subsequent engine inspection revealed cracks in the cylinder head of an adjacent engine cylinder. Lloyd's Register Technical Investigations were asked to investigate the damage and establish whether the two incidences had a common cause.

The primary cause of damage to the first cylinder head, valve and running gear was a detached inlet valve head (tulip), which had become separated as a result of the development of a fatigue crack from multiple origins associated with a bend in the valve spindle.

Fibrous debris was found in the valve bridge oil-way which restricted the oil flow to the sliding surfaces of the valve bridge piece and valve guide post. Galling and seizure damage were identified on the components. This damage had impaired the valve motion and allowed contact with the head of the piston.

In the second incident, cracking was found on the cylinder head between the exhaust valve seat and injector sleeve bore. The cracking was characteristic of an increase in the thermal stresses between these sections.

The cylinder head cooling water spaces were contaminated with a black oily substance. The substance was identified using gas chromatography analysis to be heavy fuel oil. The coating of oil covering the water spaces impaired the heat transfer to the water, increasing both the temperature gradient and stresses in the thin hottest sections of the flame deck.

It is improbable that the two damages were linked.

LESSON

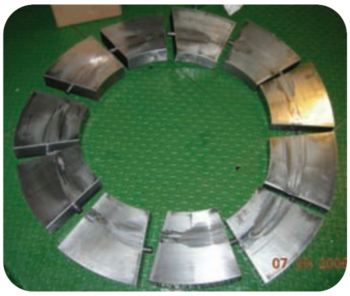
Often successive failures can be linked to a common cause, but at times they will be due to different circumstances. Failure investigation, therefore, requires that all factors and circumstances are taken into consideration and judged with relevant experience, to determine the correct causes.

CASE STUDY 10

Thrust block

SUBJECT VESSEL TYPE
Oil Tanker

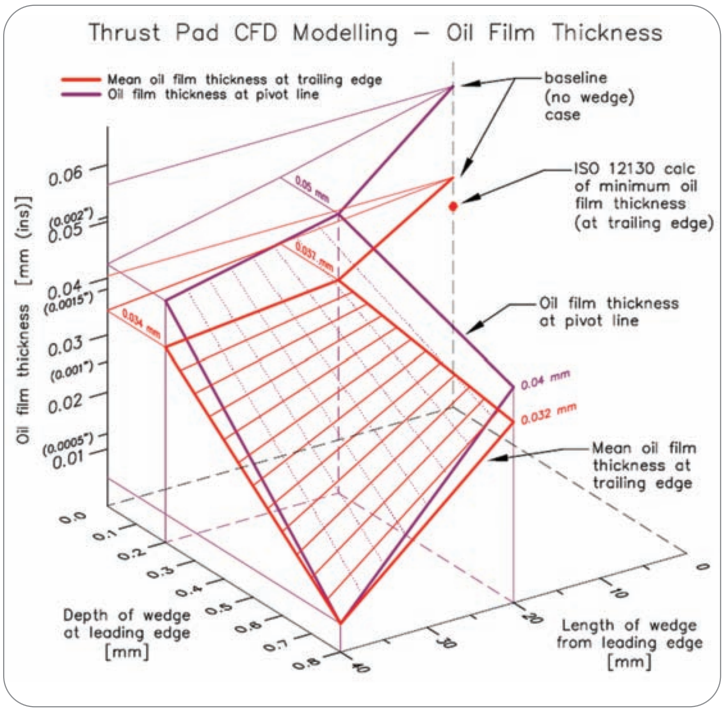
ISSUE
Repeated failure of thrust block bearings



A twin screw diesel electric oil tanker experienced repeated failures of the starboard shaftline axial thrust bearing. The two sets of propulsion shafting consisted of an electric motor directly coupled to a thrust shaft, intermediate shaft, propeller shaft, and fixed pitch propeller. Each thrust shaft was supported by oil lubricated white metal bearings each side of the thrust collar with the ahead and astern thrusts taken by eleven tilting pads each side of the collar. Overheating and wiping of the white metal of the tilting pads occurred on three separate occasions early in the life of the vessel.

Extensive work was undertaken by Technical Investigations (TI) before attending onboard the vessel. A review of the complete shafting design was undertaken and third-party reports from previous trials and measurements were re-assessed. The propulsion shaftline torsional, lateral and axial dynamic characteristics were modelled using Lloyd's Register shafting software suite. The shaft alignment was studied to investigate possible effects on the dynamic characteristics.

A comprehensive onboard investigation was undertaken. Simultaneous dynamic measurements were made of the significant parameters on both shaftlines in order to compare their behaviour over the full operational manoeuvring and speed ranges ahead and astern. The theoretical modelling carried out beforehand allowed immediate evaluation of the results within the short time available onboard.



At the same time, the design and operation of the tilting pad elements was investigated using Computational Fluid Dynamics (CFD). Modelling was carried out to investigate the effect of varying the oil viscosity, the operating temperature and different designs of leading edge geometry on the bearing oil film thickness. The minimum thickness at service speed was estimated to be 32 microns (0.032 mm).

The cause of the failure was eventually identified using a simple mechanical dial-gauge indicator. Relative movement between the upper and lower thrust block casing halves was occurring as a result of loosening of the holding-down bolts. The unequal reactions in the upper and lower casings overloaded thrust pads which reduced the oil film thickness and resulted in overheating and failure.

Recommendations were made to replace the existing thrust block holding-down bolts with hydraulically tightened, expanding sleeve type bolts.

LESSON

Complex hypotheses, measurements and analysis are often deployed in determining and effectively rectifying the cause of failure. It is a sobering thought, however, that the cause of the failure can occasionally be identified with basic instrumentation and can be due to something much simpler.

Technical investigations expertise

Dr Claus Myllerup

Dr Claus Myllerup joined Ødegaard & Danneskiold-Samsøe (ØDS) in 1996 following a two year period with Castrol as Technical Consultant.

When he joined as manager of the Machinery Dynamics Group Dr Myllerup supervised and carried out numerous experimental, computational, and theoretical consulting projects within the field of machinery dynamics. The range of clients was wide, but they were mainly within the oil and gas industry.

During 2005 ØDS was acquired by Lloyd's Register, he was by then the Deputy Managing Director at ØDS. Under his leadership the company has grown from 15 to 55 staff and the client base has grown to encompass most of the major players in the industries the company serves.

Dr Myllerup is a member of the Society of Engineers of Denmark and the American Society of Mechanical Engineers.

Peter Filcek

Peter Filcek joined the Technical Investigations (TI) of Lloyd's Register in 1979 and has worked on a wide variety of marine and land failure investigations and measurements. He became Principal Surveyor in charge of Failure Investigations in 2000, and Technical Manager in 2004 responsible for technical matters within TI.

He graduated in Marine Engineering at Newcastle-upon-Tyne and obtained experience of engine manufacture, ship repairing, marine engineering, and the power station industries before joining Lloyd's Register in 1977. He trained as an Engineering Surveyor in plan approval and in the port of Rotterdam.

John Maguire

John Maguire Joined Lloyd's Register in 1989 within the HQ-Industrial Division. He transferred to HQ-Engineering Services Group in 1994, into the Technical Investigations (TI). He was appointed Engineering Projects Principal in TI in 1999, and Development Manager in 2004. For the last four years he has been responsible for developing the products and services offered by TI, including all related material, and also responsible for carrying out special technical investigations.

Prior to Lloyd's Register, he was a civil engineer with WS Atkins from 1976, leading to chartered engineer status in 1980. Between 1976 and 1989 he spent periods in the UK, Algeria, Morocco and Saudi Arabia on a variety of assignments.

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Lloyd's Register ODS

Three years ago Dr Myllerup was appointed a Senior Vice President of Lloyd's Register and Head of Lloyd's Register Technical Investigation & Analysis with the responsibility to integrate Ødegaard & Danneskiold-Samsøe (ØDS), the Technical Investigation Department and Structural Analysis Services (SAS).

From the 1 July 2008 these services have been integrated into a single entity known as Lloyd's Register ODS and the growth strategy is illustrated by the acquisition of Martec in February 2008 and the opening of the Shanghai office in July 2008.

Lloyd's Register ODS services are offered across all business streams, but it is a division of the Marine Consultancy Services.

TECHNICAL MATTERS

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